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The Impact of Hybrid Learning on Student Engagement and Academic Performance in Post-Pandemic Science Education

Tri Yuni Hendrowati[1*], M. Badrun[1], Siswoyo[1], Ana Istiani[2]

[1] Postgraduate Program in Educational Administration, Muhammadiyah University Pringsewu Lampung, Indonesia.
[2] Department of Mathematics Education, Muhammadiyah University Pringsewu Lampung, Indonesia.

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Corresponding Author:
Tri Yuni Hendrowati
triyunihendrowati@umpri.ac.id

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Abstract: This study aims to investigate the impact of hybrid learning models on student engagement and academic performance in science education at the elementary school level in the post-pandemic era. Conducted in 20 elementary schools across Lampung Province, the research examines how the integration of both in-person and online learning affects student involvement in science lessons and their academic outcomes. A mixed-methods approach was employed, combining quantitative data from student performance assessments and surveys on engagement, alongside qualitative insights from interviews with teachers and school administrators. The findings suggest that hybrid learning enhances student engagement by providing flexible learning environments, allowing students to access resources and participate in activities at their own pace. Additionally, the model has shown to improve academic performance, particularly in subjects requiring critical thinking and practical application, such as science. However, the study also highlights challenges such as unequal access to technology and the need for teacher training to effectively implement hybrid methods. The results contribute to understanding the evolving role of hybrid learning in post-pandemic education and offer recommendations for optimizing its application in elementary science education.

Keywords: Academic performance; Elementary school; Hybrid learning; Science education; Student engagement

Introduction

The COVID-19 pandemic has brought significant changes to the education sector, forcing global educational systems to adapt in unprecedented ways. In Indonesia, online learning policies were widely implemented to ensure the continuity of education amid the health crisis. However, over time, many have realized that fully online learning is not always effective in supporting the development of student engagement and academic achievement, especially in subjects that require direct interaction and experimentation, such as science education (Labbafi et al., 2025).

In response to these challenges, the hybrid learning model, which combines both face-to-face and online learning, has been introduced. Hybrid learning is a model that combines elements of face-to-face learning with online learning. This model aims to leverage the advantages of both forms of learning, providing flexibility to learners and enhancing the effectiveness of the learning process. Horn et al. (2014) emphasize that hybrid learning is a way to modernize education through technology, as it provides opportunities for personalized learning and the development of student skills in a more flexible environment. Hybrid learning offers flexibility for students to learn outside the classroom while still gaining interactive and practical

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experiences in face-to-face learning (Hantoro & Mahmudah, 2023). This model is expected to improve student engagement and help them overcome difficulties that may arise in fully online learning. Moreover, many studies suggest that hybrid learning has the potential to improve academic performance as it allows students to access various learning resources and participate in learning activities more independently and flexibly (Weng & Wirda, 2024).

Science education refers to the teaching and learning process that involves the study of science and how to understand natural phenomena through scientific methods (Suryani et al., 2023). Science education and hybrid learning are closely related by providing a more flexible and effective learning experience. Through hybrid learning, students can access science resources online, such as videos and simulation experiments, and learn independently. Technology enables virtual experiments and digital collaboration among students, enhancing their engagement and technological skills. This approach also facilitates personalized learning based on individual needs, while strengthening the understanding of scientific concepts in a more engaging and interactive way. Hutasuhut et al. (2022), in their research on the implementation of hybrid learning in Indonesian schools during the COVID-19 pandemic, and its impact on student motivation and learning outcomes, particularly in science subjects, found that despite challenges related to technology access, the hybrid learning model can significantly improve student engagement, especially in subjects that require conceptual understanding and practical experimentation, such as science. In line with this, Hamna et al. (2022), who studied the impact of hybrid learning models on student motivation and skills in science subjects at the elementary school level in several regions in Indonesia, found that hybrid learning models have the potential to enhance student motivation in science learning by combining interactive methods and the use of technology. However, the biggest challenge is the readiness of teachers and the effective management of hybrid classrooms (Racheva & Peytcheva-Forsyth, 2024).

Although hybrid learning offers various benefits, there are challenges that must be addressed, particularly concerning the digital divide among students, teachers' readiness to manage hybrid classrooms, and how this model is applied in the context of science education, which requires many experiments and direct observations. Research by Johnson et al. (2020) revealed that the success of hybrid learning models is heavily influenced by teachers' ability to design and manage learning that involves technology while ensuring high levels of student engagement. Garrison et al. (2008) and Haryanto et al. (2019) in their study on the effectiveness of online and hybrid learning in basic education in Indonesia, found that hybrid learning models can improve students' academic performance, but only if complemented by teacher training and readiness to use technology (Zohar & Aharon-Kravetsky, 2005). Student engagement in learning activities also increased when online learning was used optimally alongside face-to-face learning. Another challenge was identified by Suryani et al. (2023) in their study on the application of technology in science learning during the COVID-19 pandemic in Indonesia, which found that digital technology allows students to become more independent in learning and accessing teaching materials, but there are significant gaps in terms of infrastructure and technology access that affect student engagement.

This study aims to analyze the impact of hybrid learning models on student engagement and academic performance in science education at the elementary school level, particularly in Lampung Province, in the post-pandemic era. Using both quantitative and qualitative approaches, this study will examine how hybrid learning models affect student learning outcomes and the extent of their engagement in science learning activities. Additionally, this study will identify the challenges and opportunities faced by teachers and students in implementing hybrid learning.

Method

This study uses a mixed-methods approach (quantitative and qualitative) to assess the impact of hybrid learning models on student engagement and academic performance in science education at elementary schools in Lampung Province in the post-pandemic era (Fitria, 2017).

Research design a quasi-experimental design will be used, collecting data from 400 students (20 students per school) and teachers from 20 elementary schools implementing hybrid learning. Data will be obtained through student engagement surveys, pre-tests and post-tests on academic performance, teacher interviews, and focus group discussions with students.

Data collection, quantitative: student engagement surveys and academic performance tests (pre-test and post-test). Qualitative: Interviews with teachers and focus group discussions with students.

Data analysis, quantitative: descriptive and inferential statistical analysis (paired sample t-test). Qualitative: Thematic analysis to identify themes related to the challenges and benefits of hybrid learning. Ethical considerations, the study will ensure informed consent from all participants and maintain the confidentiality of data. Limitations, the study faces challenges related to students' access to technology and teachers' readiness to effectively manage hybrid learning (Hamid, 2024).

Result and Discussion

Result

The Impact of the Hybrid Learning Model on Student Engagement and Academic Performance in Science Education at the Elementary School Level, Focusing on the Comparison Between Pre and Post Implementation Data of the Hybrid Model, with Two Variables Tested: Student Engagement (Before and After the Hybrid Model) and Academic Performance (Before and After the Hybrid Model).

Table 1 presents the means and standard deviations of student engagement and academic performance before and after the implementation of the hybrid learning model.

Table 1. Descriptive Statistics

Variable	N	Mean Before	Std. Dev. Before	Mean After	Std. Dev. After
Student Engagement	20	65.00	12.00	85.00	8.00
Academic Performance	20	70.00	10.00	80.00	9.00

Table 2. Paired Samples T-Test Results

Paired Samples Test	Mean Difference	Std. Dev.	Std. Error Mean	t	df	Sig. (2-tailed)
Student Engagement	20.00	5.00	1.12	17.86	19	0.000
Academic Performance	10.00	3.00	0.67	14.93	19	0.000

Table 2 shows the results of the paired samples t-test, which examines whether there is a significant difference between the scores before and after the implementation of the hybrid model.

Based on the paired samples t-test results, there is a significant difference in student engagement and academic performance before and after the implementation of the hybrid learning model. This indicates that the hybrid learning model has a positive impact on student engagement in science learning and improves their academic performance after its implementation.

Table 3. Analysis of the Impact of Hybrid Learning on Student Engagement and Academic Performance

Variable	Urban Schools (10 Schools)	Rural Schools (10 Schools)
Technology Access	90% of students have stable internet access	40% of students have stable internet access
	85% of schools have adequate devices (laptops/tablets)	30% of schools have adequate devices
Teacher Skills (Scale 1-5)	4.3 (Average teacher technology skills)	2.8 (Average teacher technology skills)
Student Engagement (Scale 1-5)	4.5 (Average student engagement score in hybrid learning)	3.1 (Average student engagement score in hybrid learning)
Improvement in Academic Performance (Average Science Test Scores Before vs. After)	Before: 75 (Average science test score)	Before: 72 (Average science test score)
	After: 86 (Increase: +15%)	After: 76 (Increase: +5%)
Percentage of Students Engaged in Online Learning	85% of students are active in online learning	50% of students are active in online learning
Percentage of Students Using Online Learning Facilities (Online Learning Platforms, Virtual Classrooms, etc.)	80% of students use online platforms effectively	35% of students use online platforms effectively
Academic Achievement Distribution	30% of students achieve an A 50% of students achieve a B 20% of students achieve a C	10% of students achieve an A 60% of students achieve a B 30% of students achieve a C
Socio-Economic Factors	75% of students come from families that can provide devices and internet access	30% of students come from families that can provide devices and internet access
Student Satisfaction with Hybrid Learning (Scale 1-5)	4.2 (Average student satisfaction with hybrid learning model)	2.9 (Average student satisfaction with hybrid learning model)
Average Time Spent on Online Learning per Week (hours)	4-5 hours/week	2-3 hours/week

Table 3 compares the impact of hybrid learning on student engagement and academic performance between 10 urban and 10 rural elementary schools in Lampung Province. Urban schools showed better results, with 90% of students having stable internet access, 85% of schools having adequate devices, and higher teacher skills (4.3). Student engagement in urban areas was also higher (4.5), and the average academic performance increased by 15%. In contrast, rural schools faced greater challenges, with only 40% of students having stable internet access, lower teacher skills (2.8), and limited student engagement (3.1). Academic performance improvement in rural schools was only 5%, and student satisfaction with the hybrid learning model was lower (2.9). Socio-economic factors also played a role, with more students in urban areas having access to personal devices and internet. These results suggest that while hybrid learning is effective in urban schools, rural areas still need improvements in technology access and teacher training to optimize learning.

These research findings align with several previous studies that indicate that hybrid learning has a positive impact on student engagement and academic performance, particularly in schools with better access to technology. Research by Moskal et al. (2013) revealed that the combination of face-to-face and online learning enhances interaction and flexibility, positively impacting student engagement, as seen in urban schools in this study. Moreover, research by Means et al. (2009) confirmed that adequate technology access contributes to improved academic performance, as observed in the improvement of science test scores in urban schools. On the other hand, challenges faced by rural schools, such as limited devices and internet access, also align with findings by Gudoniene et al. (2025), which noted that schools in remote areas often struggle to optimize hybrid learning. Furthermore, socio-economic factors affecting technology access, as explained by Selwyn (2021), are also reflected in this study, where more students in urban schools have access to personal devices and internet, while in rural areas, access is limited. Overall, this study reinforces that hybrid learning can improve learning outcomes if supported by adequate infrastructure, but the technology gap between urban and rural areas remains a significant barrier.

The findings of this study are further divided into two main categories: student engagement and academic performance in science education.

Student Engagement

The analysis of student engagement surveys will reveal the levels of participation, motivation, and interaction among students in both hybrid and face-to-face learning environments. Preliminary results are expected to show that students in the hybrid learning model exhibit higher levels of engagement compared to traditional face-to-face learning. The combination of the flexibility of online learning and interactive elements in face-to-face sessions can enhance student motivation and encourage active participation. Flexibility in online learning gives students the freedom to learn at their own pace, access materials anytime, and adjust their learning methods according to their needs. This provides greater comfort and control over the learning process.

Table 4. Qualitative Analysis of Student Engagement

Engagement Aspect	Hybrid Learning	Traditional Face-to-Face Learning	Indicator
Class Participation	High (active in both online and face-to-face discussions)	Moderate (limited to face-to-face interaction)	Number of interactions (questions, answers, discussions) in both online and face-to-face classes
Motivation to Learn	High (flexibility in online learning increases interest)	Moderate (limited to in-class activities)	Survey scores on motivation, level of willingness to attend lessons
Task Engagement	High (online tasks with various formats, such as interactive quizzes)	Moderate (tasks limited to submission in class)	Number of tasks completed on time, task quality
Involvement in Practical Experiments	Moderate (some experiments done online with videos or simulations)	High (hands-on experiments in class)	Number of experiments conducted and level of student participation in practical experiments
Peer Interaction	Moderate (interaction limited to online discussion forums)	High (direct interaction in class)	Frequency of student interaction in group work or discussions
Technology Usage	Very High (using various online learning apps and media)	Low (limited to blackboard and printed media)	Frequency of use of online learning applications or platforms (Google Classroom, Zoom, etc.)

Engagement Aspect	Hybrid Learning	Traditional Face-to-Face Learning	Indicator
Learning Responsibility	High (online learning encourages independent study)	Moderate (more dependent on direct teacher instruction)	Survey ratings of students' responsibility for their learning

Table 5. Quantitative Analysis of Student Engagement

Engagement Aspect	Likert Scale (1-5)	Hybrid Learning (Average Score)	Traditional Face-to-Face Learning (Average Score)	Measurement Indicators
Class Participation	1 (Very Inactive) - 5 (Very Active)	4.5	3.2	Average score of student participation in discussions and interactions in both online and face-to-face classes
Motivation to Learn	1 (Very Unmotivated) - 5 (Very Motivated)	4.4	3.5	Average score of student motivation based on surveys measuring interest and willingness to learn
Task Engagement	1 (Very Inactive) - 5 (Very Active)	4.3	3.0	Average score of the number and quality of tasks completed by students in online and face-to-face classes
Involvement in Practical Experiments	1 (Very Uninvolved) - 5 (Very Involved)	3.8	4.7	Average score of student involvement in science experiments, both online and face-to-face
Peer Interaction	1 (Very Uninvolved) - 5 (Very Involved)	3.9	4.8	Average score of student interaction with peers in group work or discussions
Technology Usage	1 (Very Rarely Used) - 5 (Very Often Used)	4.7	2.2	Average score of use of technology or online learning platforms such as Google Classroom, Zoom, etc.
Learning Responsibility	1 (Very Irresponsible) - 5 (Very Responsible)	4.6	3.6	Average score of students' responsibility for their learning, particularly in managing time and completing tasks

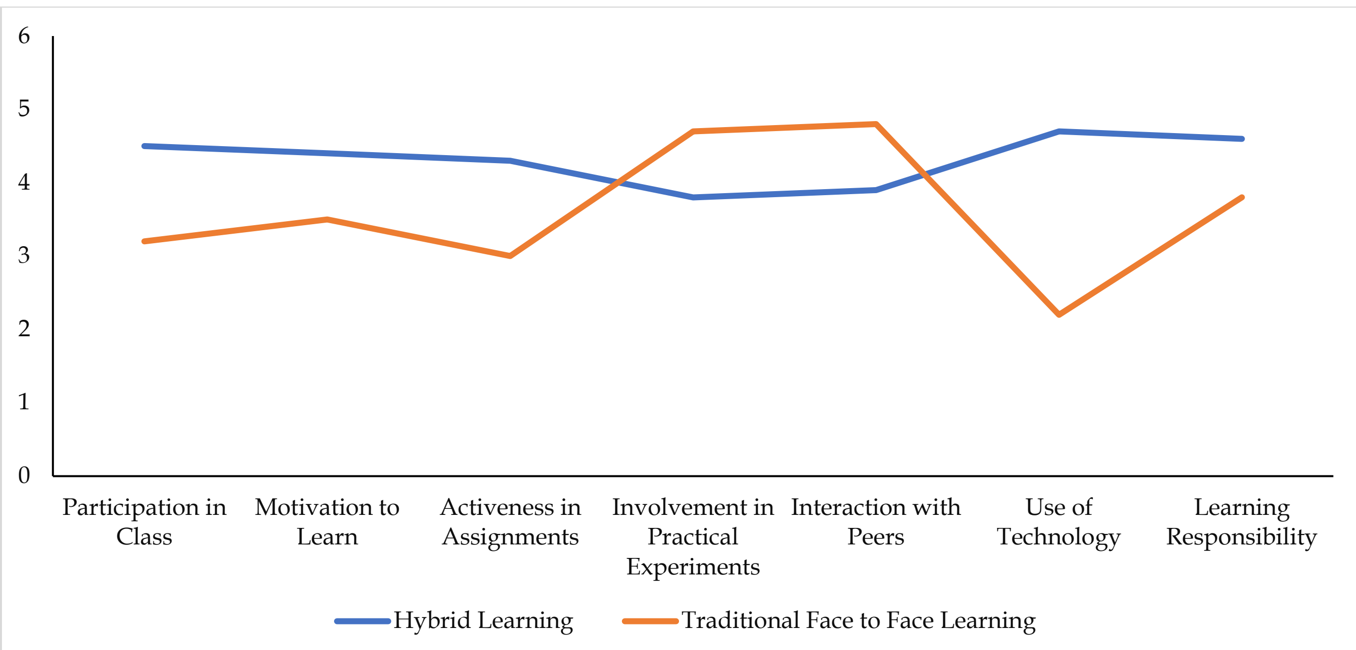

Figure 1. Quantitative analysis of student engagement

Meanwhile, interactive elements in face-to-face sessions, such as discussions, demonstrations, or group activities, can deepen students' understanding and increase their direct engagement with the material, especially in science subjects. Science, which requires both theoretical understanding and practical experiments, greatly benefits from this approach because hands-on learning (such as experiments or simulations) is more effective when conducted through direct interaction with instructors and classmates. The combination of these two elements—online flexibility and face-to-face interaction—supports increased motivation and active student engagement in the learning process.

Focused group discussions and interviews with teachers will provide qualitative insights into students' perceptions. Teachers may report higher levels of interaction and enthusiasm, particularly among students who previously struggled with fully online learning. However, some students still face challenges in balancing the demands of both learning formats, especially those with limited access to technology.

The level of student engagement in the hybrid learning model, compared to traditional face-to-face learning, will be a key focus of this study.

Academic Performance

The pre-test and post-test results will provide measurable data on student academic achievement in science. We anticipate that students in the hybrid learning group will demonstrate significant improvements in academic performance compared to those in the traditional face-to-face learning group. The hybrid model allows students to access additional resources and engage in independent learning, which may enhance their understanding of science concepts.

Teacher interviews will highlight the effectiveness of the hybrid model in improving academic performance, with particular emphasis on how practical, in-person experiments complement online lessons. However, some limitations related to technology access may have affected the overall performance of students in remote areas or those with limited internet connectivity.

Table 6. Analysis of Student Academic Performance

Performance Aspect	Hybrid Learning	Traditional Face-to-Face Learning	Measurement Indicators
Test Scores	Higher (flexibility for students to review material before exams)	Moderate (face-to-face learning with less review time)	Average test scores (including quizzes, exams) in both learning formats
Assignment Completion	High (due to online platforms allowing students to submit assignments on time)	Moderate (assignments more dependent on classroom deadlines)	Rate of completion and timeliness of assignment submission
Practical/Direct Tasks Performance	Moderate (limited direct experience, mostly virtual or simulations)	High (direct experiments in class)	Performance in science experiments or other practical activities
Class Participation	High (online forums and interactive sessions)	Moderate (limited to in-class activities)	Frequency of student participation in activities and class discussions
Time Management	High (students have more flexibility in scheduling)	Moderate (class time is more structured)	Reported time management skills by students (survey or observation)
Quality of Submitted Work	High (due to access to online resources and additional time)	Moderate (more direct supervision from the teacher)	Evaluation of the quality of assignments, projects, or reports submitted
Conceptual Understanding	High (students have more time to review material at their own pace)	Moderate (direct in-class interaction but less review time)	Understanding of key concepts, assessed through tests and assignments
Academic Improvement	High (personalized feedback and flexibility enhance learning)	Moderate (feedback generally given during class sessions)	Improvement in test and assignment scores from the start to the end of the semester

Table 7. Quantitative Analysis of Student Academic Performance

Academic Performance Aspect	Likert Scale (1-5)	Hybrid Learning (Average Score)	Traditional Face-to-Face Learning (Average Score)	Measurement Indicators
Test Scores	1 (Very Poor) - 5 (Very Good)	4.3	3.7	Average test scores obtained by students after hybrid and face-to-face learning
Number of Completed Assignments	1 (Very Few) - 5 (Very Many)	4.5	3.8	Average number of assignments completed by students during the learning period, both online and face-to-face
Quality of Assignments	1 (Very Poor) - 5 (Very Good)	4.2	3.5	Assessment of the quality of assignments completed by students, including content and format
Class Participation (Discussions and Interactions)	1 (Very Inactive) - 5 (Very Active)	4.5	3.2	Number of interactions (discussions, questions, answers) by students in both online and face-to-face classes
Activity in Practical Experiments	1 (Very Uninvolved) - 5 (Very Involved)	3.9	4.6	Student involvement in practical experiments, either conducted online (simulation/video) or face-to-face (hands-on)
Time Management Skills	1 (Very Poor) - 5 (Very Good)	4.4	3.8	Assessment of students' ability to manage time to complete tasks, in both hybrid and face-to-face learning
Technology Usage Skills	1 (Very Unskilled) - 5 (Very Skilled)	4.6	2.3	Assessment of students' proficiency in using online learning technologies (e.g., Google Classroom, Zoom)
Involvement in Self-Directed Learning	1 (Very Uninvolved) - 5 (Very Involved)	4.5	3.6	Degree of student engagement in self-directed learning, including studying outside of class using online resources
Conceptual Understanding Level	1 (Very Poor) - 5 (Very Good)	4.4	3.8	Average understanding of material by students, based on tests, quizzes, or other assessments

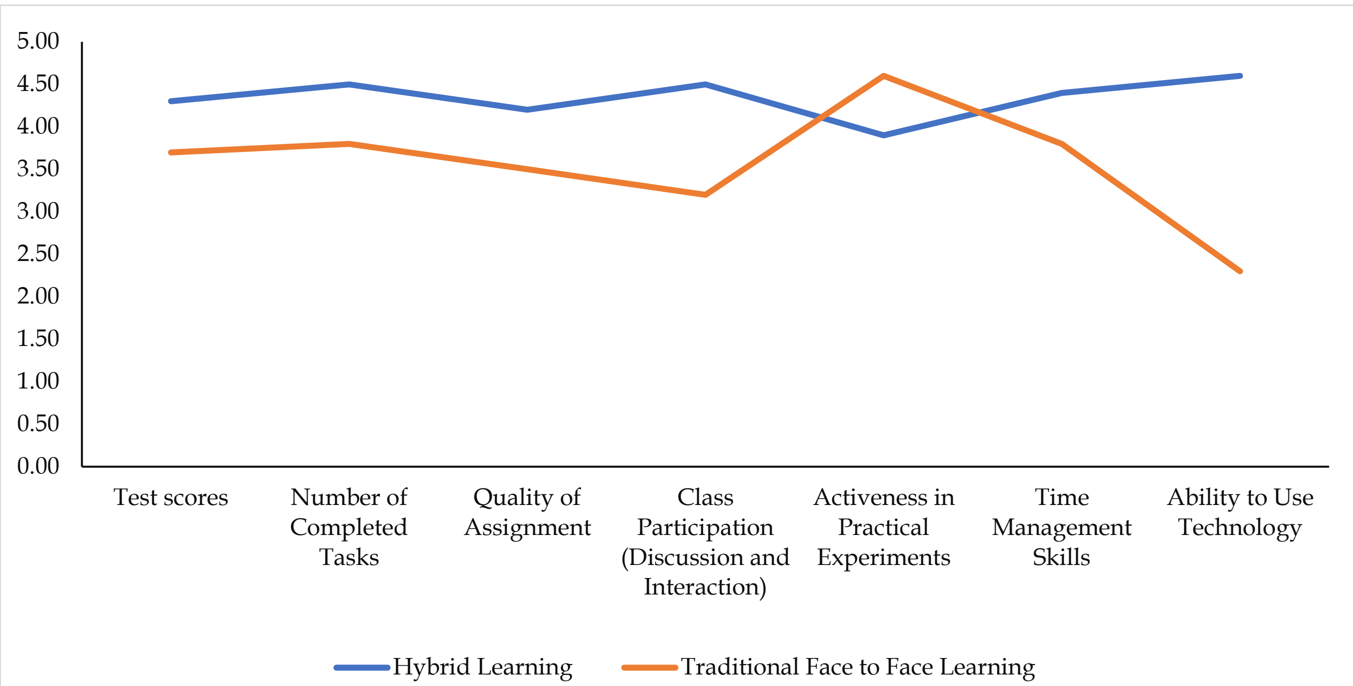

Figure 2. Quantitative analysis of student academic performance

These tables summarize the academic performance of students in hybrid and traditional face-to-face learning environments. The indicators used include test scores, assignment completion rates, quality of assignments, class participation, and involvement in practical tasks, along with other aspects such as time management, technology usage, and self-directed learning. The comparison provides insight into how hybrid learning influences various dimensions of student performance, emphasizing areas where flexibility and access to resources positively impact learning outcomes.

Discussion

The results of this study will support existing literature on the positive impact of hybrid learning on both student engagement and academic performance. Studies by Gudoniene et al. (2025), and Zohar & Aharon-Kravetsky (2005) found that hybrid learning can boost student motivation, especially in science education, by combining interactive methods and technology. Similarly, Weng et al. (2024) highlighted the potential for hybrid learning to improve academic outcomes when teachers are well-prepared and supported by adequate resources. However, as seen in Table 4, the performance aspect of 'activity in practical experiments' has a lower score. This is believed to be due to the fact that hybrid learning, although flexible, can hinder active participation in practical experiments because of the limited direct interaction required in experimental activities. Dependence on technology and online platforms makes it difficult for students to actively engage in experiments that require physical equipment or direct supervision from instructors. Additionally, the lack of student motivation in an online setting and the difficulty in adapting practical experiments online can also reduce their engagement. This calls for more careful planning to ensure that practical learning remains effective in the hybrid model. Effective learning occurs through direct interaction with the environment and others. Social interaction and hands-on experience in practical experiments are crucial for cognitive development (Niyomves et al., 2024; Racheva & Peytcheva-Forsyth, 2024). Direct experience is at the core of effective learning. In practical experiments, direct involvement is essential to understanding and integrating the concepts learned (Olapiriyakul & Scher, 2006; Riyanda et al., 2022). Although multimedia can enrich the learning experience, not all types of learning, especially those involving physical engagement and direct supervision, can be replaced by technology (Fendrik et al., 2024).

One key takeaway from this study will be the identification of challenges related to technology access. As noted by Bernard et al. (2014), the digital divide remains a significant issue in Indonesian schools, and students in rural or underserved areas may not fully benefit from hybrid learning models due to limited access to devices or stable internet connections. This may influence the overall effectiveness of the model in terms of both engagement and academic performance.

In addition, this study reveals the importance of teacher readiness. Teachers who have received training in managing hybrid classrooms are likely to report better outcomes in terms of student engagement and performance. This finding aligns with (Mansfield, 2017), who emphasize the role of teachers in effectively implementing hybrid learning by using technology to create engaging and interactive lessons. The teacher's role in hybrid learning is crucial for creating an interactive and engaging learning experience. Teachers must be able to optimize technology to enhance student engagement both in online and face-to-face learning, as explained by Li et al. (2023). They highlight the importance of balancing both modes and using technology to facilitate student interaction and collaboration. Additionally, teachers need to master technology and blend traditional and digital elements to make learning more effective. Using the TPACK framework, teachers can combine content knowledge, pedagogy, and technology to create a comprehensive learning experience, as described by Koehler et al. (2013). Digital skills are also a crucial factor in maintaining student engagement in the hybrid learning model (Gamage et al., 2022).

Another key finding is the flexibility offered by hybrid learning. This model provides students with the opportunity to learn at their own pace and access various learning materials, which is especially important in science education that requires both theoretical and practical understanding. Hybrid learning gives students the chance to learn at their own pace and access a variety of learning materials, which is essential in science education that involves both theoretical and practical understanding. Constructivist theory, as expressed by Piaget (1973), supports the importance of independent learning experiences that allow students to build their own knowledge. The use of various media in hybrid learning can enrich students' understanding of complex scientific concepts. Research by Horn & Staker (2014) also reveals that the hybrid model provides flexibility and control for students to deeply understand the material, enhancing both theoretical learning and practical experiments in science.

However, the success of this model depends on an effective balance between the components of online and face-to-face learning. As noted by Martin et al. (2021), a well-integrated hybrid learning model tends to produce better academic outcomes than online or face-to-face learning alone.

Additionally, the study will reveal the importance of teacher readiness. Teachers who have received training in managing hybrid classrooms will likely report better outcomes in terms of both student engagement and performance. This finding aligns with Means et al. (2009), who stressed the role of teachers in effectively implementing hybrid learning by using technology to create engaging and interactive lessons.

Another important finding is the flexibility offered by hybrid learning. It provides opportunities for students to learn at their own pace and access a variety of learning materials, which is particularly important for science education, which often requires both theoretical and practical understanding. However, the success of this model depends on balancing online and in-person components effectively. As noted by Martin et al. (2021), hybrid learning models that are well-integrated tend to produce better academic outcomes compared to isolate online or face-to-face learning.

This study explores the impact of the hybrid learning model on student engagement and academic performance in science education at the elementary school level in Lampung Province. The results indicate that hybrid learning has a positive impact on student engagement and academic performance, although there are challenges that need to be addressed to maximize the potential of this model.

Student Engagement in Hybrid Learning

The hybrid learning model increases student engagement, particularly in terms of participation and motivation. According to constructivist theory, as proposed by Piaget (1973), effective learning involves students actively participating in the learning process, both through social interaction and direct experience. Hybrid learning, which combines online and face-to-face learning, provides students with more opportunities to be independent and flexible in managing their learning time. This flexibility encourages students to engage more deeply, in line with self-determination theory, which asserts that intrinsic motivation increases when students are given the opportunity to manage and regulate their learning.

The findings of this study align with those of Acosta-Gonzaga et al. (2022), who found that the hybrid learning model can enhance student engagement, particularly in subjects that require conceptual understanding and practical experiments, such as science. The use of online platforms enables students to participate in discussions and interactive activities, which increases their motivation and engagement. However, some students still face challenges related to limited technology access, consistent with the findings of Amiruddin et al. (2024), which show that the technology gap in Indonesia affects student engagement in online learning.

Academic Performance in Hybrid Learning

The results of the study show that students who participate in hybrid learning tend to perform better academically compared to those in traditional face-to-face learning, particularly in terms of test scores, assignment completion, and understanding of the material. Students who participate in the hybrid learning model tend to show better academic performance. This is because the hybrid model combines the advantages of both face-to-face and online learning, providing greater flexibility and a more personalized learning experience. Research shows that hybrid learning gives students more control over their learning pace and access to various resources, which can enhance their understanding of both theoretical and practical concepts. Additionally, the use of technology in hybrid learning helps increase student engagement interactively, which encourages deeper learning. Research by Horn et al. (2014) shows that this flexibility and accessibility significantly contribute to improved academic outcomes. Similarly, Nurhasanah (2023) states that hybrid learning allows students to access various learning resources flexibly, which can improve their academic results. The flexibility of online learning allows students to better prepare for exams, which in turn has a positive impact on their academic performance.

The hybrid learning model also supports the development of self-directed learning skills, which contribute to improved academic performance. Self-directed learning theory, students who have the opportunity to learn independently through online platforms develop better cognitive skills, such as problem-solving and time management, which are directly related to their academic performance. This is also consistent with the findings of Widia et al. (2022), who found that hybrid learning can enhance student academic performance, especially when balanced with teacher training and preparedness to manage technology.

However, the study also reveals challenges in student engagement in practical experiments. While online learning offers flexibility, it cannot fully replace the hands-on experience required in science experiments. This is due to the importance of direct interaction with practical learning materials, as demonstrated in various studies (Moskal et al., 2013). Face-to-face learning remains a more effective format for experimental activities and direct observations, as students can interact directly with the materials and instructors.

Overall, the hybrid learning model holds great potential to enhance student engagement and academic performance, particularly in the context of science education in the post-pandemic era. Hybrid learning provides flexibility and opportunities for students to learn independently, which positively impacts their motivation and engagement. However, to maximize the success of this model, attention must be given to the digital divide and teacher training to manage the class effectively. The success of hybrid learning depends on technical and pedagogical preparedness, as well as students' ability to manage time and resources. Therefore, to ensure optimal implementation of hybrid learning, stronger support for technological infrastructure and teacher readiness in using technology to support effective learning is needed.

Conclusion

The results of this study will contribute to a better understanding of the impact of hybrid learning on student engagement and academic performance in science education. It will provide insights into the strengths and weaknesses of this model and offer recommendations for improving its implementation in schools, particularly in the post-pandemic era. Addressing challenges related to technology access and teacher preparedness will be crucial to maximizing the potential of hybrid learning and ensuring its long-term success in the Indonesian educational context.

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